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ABSTRACT

A team theoretic model that establishes a criterion (decision rule) for a financial institution branch to report exceptional loan requests to headquarters for action was compared to such choices made by graduate industrial management students acting as financial vice-presidents. Results showed that the loan size criterion specified by subjects was typically greater than the optimal criterion when the optimal criterion was small relative to the maximum loan size, and less than the optimal criterion when the optimal criterion was large relative to the maximum loan size. That is, subjects specified criteria that would result in the reporting of too few exceptions (a case of informational overdecentralization) and too many exceptions (a case of informational overcentralization) when the optimal criterion was relatively small and large respectively. The behavior exhibited was attributed in part to a subject's utility function, which was inferred to have a Friedman-Savage double inflected structure. (Author)

INFORMATION CENTRALIZATION OF ORGANIZATIONAL INFORMATION STRUCTURES VIA REPORTS OF EXCEPTIONS

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A central issue in organizational and management information systems (MIS) design concerns the choice of an optimal information structure for a given organization. The economic theory of teams as developed by Marschak and Radner [3] provides a normative framework, based on expected utility theory, for determining an organization's optimal information structure. Briefly, team theory is an extension of individual decision theory to the multi-person situation where there exists a complete sharing of goals and beliefs among team members, and the mutual objective is to maximize the team's expected utility based on the separate actions of each member.[1] The present study investigated descriptive versus normative choices of organizational information structures for loan activities in a financial institution via a mechanism known as Reports of Exceptions.

Reports of Exceptions

An organization's information structure is defined as being or not being completely centralized or decentralized when all its members respectively have or do not have the same information with which to take individual actions. To illustrate the centralization versus decentralization distinction, suppose, for example, that there are n organization members, and that each member observes something unique about the environment and then takes some action in his responsibility domain. If there is no communication among the members, then each member's information structure is different and he acts solely on what he alone observes (i.e., the organizational information structure is totally decentralized). On the other hand, if there is complete communication among members, then everyone acts on the same information (i.e., the organizational information structure is completely centralized). The latter information could, for example, be generated by all members communicating their observations to a central agency, which computes the best actions and communicates them back to the corresponding members as instructions to be implemented [3: 187]. (Complete informational centralization could, of course, be achieved in other ways, e.g., if all members observed the same information).

In a real organization, rarely does one encounter the extremes of no communication or complete communication just described. Rather, one finds that numerous devices are used to bring about a partial exchange of information. One particularly efficient and often used device of this kind is suggested by the phrase "management by exception." Suppose, for example, that the possible values of member *i*'s observation are partitioned by some criterion or decision rule into subsets labeled exceptional and ordinary. Assume further, that, whenever member *i*'s observation is ordinary, he bases his action upon that observation, whereas whenever his observation is exceptional he reports it to a central agency, or manager, who then decides the joint values of the decision variables of all *i* members who have reported exceptional observations, on the basis of all those exceptional observations (and possibly other information as well). That is, additional information is brought to bear specifically upon those action variables that are associated with unusual observations. The information thus generated might be called Reports of Exceptions (or more accurately, if somewhat colloquially, "passing the buck"). Such instruments are ubiquitous in contemporary organizations and are often used in making loan decisions, capital budgeting decisions, governmental decisions, tactical military decisions, production information system design decisions, etc. For example, it is often used as a mechanism whereby individuals lower in the organization hierarchy, who have limited experience and information, handle the mundane or ordinary situations, but report exceptional (extraordinary) situations to individuals higher in the organization hierarchy for their action. Team theory provides a basis for development of a prescriptive decision rule for determining the optimal partitioning of a member's observations into ordinary and exceptional values when organization members' interests are congruent [3:206-217].

Scope of Research

The aim of this paper is to report the results of a preliminary experiment which was conducted to provide a basis for understanding how Reports of Exceptions criteria are established. While the study could have been performed by actual observation and analysis in a real organization, laboratory experimentation was chosen, as an initial step, for purposes of control.

In the paper, subjectively determined criteria for reporting exceptions involving loan activities in a financial institution were compared to those prescribed by a team theoretic model in an effort to discover if any systematic differences existed between such descriptive and normative determinations. Specifically, the study attempted to (1) examine subject's sensitivity to several value and risk variables (viz, scrutiny costs, profit rates, prior probabilities, and error probabilities) which bear on establishing a criterion for reporting exceptional loans and (2) observe the subjects' propensities to overcentralize or overdecentralize information structures based on the selection of such Reports of Exceptions criteria.

Although there has been considerable theoretical discussion of the problem of optimal organizational information structures, principally in the economics literature (e.g., [4]), there has been only one such published empirical study [2] and none concerning Reports of Exceptions.

Method

Subjects

Subjects were 100 advanced graduate students enrolled in the master's program in industrial administration at Purdue University. All participated on a voluntary basis.

Task[2]

Subjects assumed the role of vice president in charge of installment lending for a consumer finance company which was composed of a headquarters and several branches. Prospective borrowers applied for loans at the branches. If the loan did not exceed a critical size, the application was scrutinized by the branch manager, and the loan was either granted or refused by him. Applications for larger loans were to be transmitted to headquarters and, after scrutiny undertaken there, the loans were granted or refused. The task of the vice president (the "organizer," or "metadecider") was to establish the optimal value of the critical loan size, L^* (i.e., which partitioned loans into ordinary and exceptional, to be processed at the branches and headquarters respectively), which maximized the firm's expected profit (the assumed "common" goal of the branches and headquarters). The lower (higher) the critical loan size established, the more centralized (decentralized) the information structure, since more (less) loans would be passed up to headquarters.

The critical loan size decision hinged on four relevant value and risk variables known to the subjects and whose parameters were provided: (1) the difference in scrutiny costs at headquarters versus a branch, $\Delta c = c_h - c_b$; (2) the likelihood that any applicant would be a "good" customer, i.e., would repay the loan, π; (3) the difference in the likelihood of an error made at a branch versus headquarters, $\Delta p = p_b - p_h$; and (4) the percent profit (rate of return) earned on a good loan as a proportion of loan size r.

To simplify the experimental problem, the following assumptions were made with regard to these variables and communicated to the subjects: (1) Every loan applied for was either "bad" or "good." If bad, it would not be repaid and would not bring any interest. If good, it would be repaid and the bank would earn a profit equal to a known proportion of the loan size. (2) The scrutiny costs at headquarters and a branch were known and independent of loan size. The cost at headquarters was greater than at a branch (i.e., $c_h > c_b$). (3) The probability that a loan was good was independent of its size, and was known. (4) The likelihood that a branch manager refused a loan when the loan was good did not depend on loan size; it was the same as the likelihood that he granted a loan when the loan was bad. (5) A corresponding assumption was true of the error probabilities at headquarters, where these errors were less than those at the branches (i.e., $p_h < p_b$). (6) No cost was assumed for communicating loan requests to headquarters.

An optimal decision rule for this problem and more realistic extensions are derived in the Appendix.

Design

The parameters of each of the four variables affecting the critical loan size decision were varied at two levels--one high and one low, resulting in a 2x2x2x2 latin square design with sixteen different problems and solutions. Subjects were randomly assigned to one of five groups. Groups 1 to 4 consisted of 85 subjects who were constrained by a $15,000 upper loan limit (L_{max}), while group 5 consisted of 15 control subjects who received identical instructions but no loan limit. An upper loan limit was imposed on most subjects because, in practice, legal restrictions and/or company policy usually require one. Each of the subjects was presented with four problems (subjects in a given group received the same four problems), randomly ordered, encountering each level of each factor in different combinations. Randomization of the order of problem presentation plus other procedures inherent in the experiment made each problem essentially independent of the others, as was verified by subjects after the experiment. Subjects were not told whether an optimal decision rule could be derived.

Procedure

Two days prior to the experiment, all subjects received some general information about the task, including how the four situational variables qualitatively affected the critical loan size decision, L^*. In addition, subjects were given some experience in making such decisions on several problem situations similar to that encountered in the experiment, with feedback on the relative size rankings of L^*, in lieu of actual L^* values. This was done to make subjects experienced decision makers and minimize experimental learning effects.

Subjects made their decisions and completed a post-experimental questionnaire concerning their strategies in one eighty-minute session without time difficulty. All subjects appeared highly motivated throughout the entire experiment, and were very interested in obtaining feedback regarding the results, which was promised as a condition of participation. Examination of subjects' strategies indicated that the stated assumptions of the problem situation were followed and that the value and risk variables used in the normative model were used by the subjects in establishing critical loan size decisions.

Results

Actual Versus Optimal Loan Sizes

Subjects' mean (L_m^a) and median responses relative to L^*, as well as the standard deviation and skewness of the response distributions are summarized in Table 1 for all 20 treatment combinations. Both standard deviation and skewness of the cells were reported because of heteroschedasticity and asymmetry of the distributions. The following observations were made from the summary data of Table 1:[3]

1. While the optimal solutions ranged from $540 to $12,120, the range of actual mean ($2,353 to $10,745) and median responses ($941 to $10,600) was smaller.
2. In 18/20 cells the mean and median responses were greater than the corresponding optimal critical loan values. In the two cases where the reverse was true, the optimal critical loan sizes were the two largest ($9,160 and $12,120).
3. The cell variances increased monotonically with increasing mean critical loan size decisions. The coefficient of variation (s/L_m^a) however, remained constant over all cells (verified using the t-statistic to test differences among the mean coefficients by partitioning the 16 cells into two groups - low and high).
4. Using Pearson's second coefficient of skewness [6: 91], 18/20 cells were found to be positively skewed, while the two remaining cells were negatively skewed.

Insert Table 1 about here.

Effects of π, Δp, Δc, r

Sensitivity of subjects' decisions to π, Δp, Δc, and r was examined by means of analysis of variance (ANOVA) using three performance measures: (1) the subject's actual decision; (2) the difference between his actual and optimal decision (an error measure); and (3) the difference between his actual and optimal decision divided by the optimal decision (a relative error measure). Because of the heterogeneity of the variances and skewness of the cell distributions, ANOVA was performed using both the actual performance measures as well as their monotonic transformations (square-root and logarithmic) [9: 397-402]. As the untransformed and transformed results were very similar, for the sake of interpretability and exposition, only the untransformed results are reported unless significant differences occurred between the two sets of results.

Actual subjects' decisions: L^a. Analysis of the actual decisions yielded main effects for all four treatment variables, but no significant interactions: (Δp: $F_{1,324} = 26.37$, $p < .0001$; Δc: $F_{1,324} = 25.28$, $p < .0001$; r: $F_{1,324} = 5.22$, $p < .03$; π: $F_{1,324} = 3.53$, $p < .06$). Hence, all four of these variables influenced the subjects' decisions, the effects were in the proper direction (e.g., as Δp decreased, L^a increased), and the magnitude of the effects as measured by the F-statistic was isomorphic with those prescribed by the optimal decision rule (i.e., the magnitude of the effect due to $\Delta p > \Delta c > \pi > r$ for both the actual and optimal results). Thus subjects' responses were properly sensitive in magnitude and direction to the importance of these variables on the decision.

<u>Difference between actual and optimal decision (error).</u> Analysis of the untransformed errors revealed a main effect for Δp ($F_{1,324} = 5.11$, $p < .023$) and two interactions, $\pi - \Delta c$ ($F_{1,324} = 3.77$, $p < .05$) and $\Delta p - \Delta c$ ($F_{1,324} = 5.53$, $p < .018$). A $\pi - \Delta p - \Delta c$ interaction, although not significant ($F_{1,324} = 2.46$, $p < .11$) is also reported since this was significant for the square-root and log data transformations. For the main Δp effect, the error when Δp was high and low was $3,032 and $1,752 respectively. That is, as the error probability difference in scrutinizing loans at the branch versus headquarters (Δp) decreased, the difference between the actual and optimal critical loan sizes ($L^a - L^*$) also decreased.

Post hoc analysis of the interactions using the Newman-Keuls procedure [9] revealed one cell significantly different from all the others (which were not significantly different) in each of the three cases (Figure 1). For the $\pi - \Delta c$ interaction, the high π, high Δc condition yielded the smallest mean error (=$1140); for the $\Delta p - \Delta c$ interaction, the low Δp, high Δc condition yielded the smallest mean error (=$703); and for the $\pi - \Delta p - \Delta c$ condition the high π, low Δp, high Δc condition yielded the lowest mean error (=$-756). Each of these conditions resulted in the highest optimal loan sizes, thus indicating that subjects were most accurate when the optimal critical loan sizes were high (Figure 1 and Table 1).

Insert Figure 1 about here.

Relative difference between actual and optimal decisions (relative error). For the relative errors the ANOVA showed main effects for π, Δp, and Δc, ($F_{1,324} = 7.33$, $p < .008$; $F_{1,324} = 42.43$, $p = .000$; $F_{1,324} = 23.17$, $p = .000$ respectively), three two-way interaction effects for $\pi - \Delta p$, $\Delta p - \Delta c$, and $\pi - r$ ($F_{1,324} = 3.90$, $p < .05$; $F_{1,324} = 4.90$, $p < .03$; $F_{1,324} = 3.30$, $p < .07$ respectively), and a three-way interaction for $\pi - \Delta c - r$ ($F_{1,324} = 4.75$, $p < .03$). For the main effects, 1) π: $\pi_{hi} = 1.20$, $\pi_{lo} = 2.10$; 2) Δp: $\Delta p_{hi} = 2.73$, $\Delta p_{lo} = .57$; 3) Δc: $\Delta c_{hi} = .85$, $\Delta c_{lo} = 2.45$. In each case, the relative error was least for each of the main effect conditions which were associated with a high optimal critical loan size (viz, π_{hi}, Δp_{lo}, and Δc_{hi}).

The interaction effects are depicted in Figure 2. In each of the interactions smaller relative errors corresponded to larger optimal loan sizes, and vice versa.

Insert Figure 2 About Here

Propensity to Overcentralize Versus Overdecentralize

Prior to the experiment it was postulated that the mean critical loan size responses on the 16 decision situations (viz, the cell mean L_m^a) in Table 1 would be less than that of the optimal solutions; i.e., the mean errors ($L_m^a - L^*$) would be negative, and reasonably independent of L^*. This hypothesis was based on the premise that people have a general tendency to overcentralize partly due to their general aversion for risk. Instead, however, the mean errors (median errors also) were positive for small L^*'s (indicating informational overdecentralization), decreased with increasing L^*, and went negative for large L^*'s (indicating informational overcentralization). This is shown by the data in Figure 3 and was verified by t-tests comparing L^a_m to L^* on each of the 16 cells. Note that for low L^*'s the positive errors were greater than were the negative errors for the high L^*'s. A similar pattern was observed using as a measure, the proportion of subjects' responses with positive errors ($L^a - L^*$). Furthermore, out of all responses in the experiment (=400), only 1 reflected a completely centralized information structure ($L^a = \$0$), while 27 indicated a completely decentralized information structure ($L^* = \$15,000$ and ∞ for the limited and unlimited groups respectively), albeit the experimental conditions resulted in L^*'s that were predominatly on the low side of the scale (Table 1).

Insert Figure 3 about here.

In sum, (1) subjects made critical loan size decisions which would have resulted in less exceptions being reported to headquarters than should have been when L* was small (overdecentralization); (2) this propensity toward overdecentralization decreased as L* increased, and (3) when L* was high subjects made critical loan size decisions which would have resulted in more exceptions being reported than should have been (overdecentralization). Moreover, the tendency to overdecentralize for low L*'s was greater than the tendency to overcentralize for high L*'s.[4]

Discussion

From an organizational perspective the major finding of this study was the subject's propensity to overdecentralize information (i.e., have fewer exceptions reported to headquarters than presented by the optimal solution) for small critical loan sizes, and overcentralize information (i.e., have more exceptions reported to headquarters than prescribed by the optimal solution) for large critical loan sizes.

Rationale

How might the above behavior be explained? Two possible, although not necessarily mutually exclusive, explanations seemed most plausible. One was artifactual and related to possible scaling effects due to the loan size limits; the other to subjects' preference or utility functions, which appeared to provide the underlying basis for subjects' statements in the post-experimental interviews.

Scaling effects. If scaling effects (i.e., due to the limits placed on loan size) were responsible for the results, there would have been (1) considerable differences between the unlimited and limited group results, (2) the standard deviations of subjects' loan size response distributions (L^a) would have been maximum at the center of the scale (i.e., for medium loan sizes) and minimum at the extremes, (i.e., for low and high loan sizes), and (3) skewness would have been correspondingly positive, symmetric, and negative at the low, medium, and high loan sizes, respectively. As it turned out, there was little difference between the limited and unlimited groups (although the unlimited group's means were somewhat greater due to some extreme responses, and the magnitudes of the standard deviation and skewness were also greater), the standard deviations monotonically increased with loan size, and skewness was positive in practically all cells (certainly at all the extremes). Hence, scaling as measured by these variables appeared to have little effect (of course, an appreciable scale effect would presumably occur at the extremes as shown by the extrapolations in Figure 3). However, the constancy of s/L_m^a for both limited and unlimited groups indicates that the above results may in part be attributable to a psychophysical phenomenon known as Weber's Law [8].

As a further check on the validity of the data, the proportion of subjects responding above and below $7500 (the middle of the scale) was also examined to determine if responses about this level were random. Two thirds of subjects' responses as compared to seven-eighths of the optimal responses were less than $7500. The results thus further support the previous findings regarding subjects' over-decentralization/centralization tendencies as well as reflecting an aggregate proclivity toward decentralization.

The change in subjects' actual responses relative to optimal responses from one decision to the next (a dynamic measure) was also investigated. Interestingly, the results showed (for <u>both</u> limited and unlimited groups) a marked tendency for subjects to over-react to small optimal decision changes (i.e., the magnitude of the actual response change was greater than the optimal response change) and to under-react to large optimal decision changes. This was independent of order and starting conditions, and seems to be related, in some sense to the "conservatism" phenomenon often found in Bayesian probability revision experiments where subjects typically over-react to small probability changes and under-react to large probability changes relative to Bayes' theorem (see, e.g., [5] and references cited therein). As the results were similar for both the limited and unlimited groups, response bias attributed to a tendency for the individual to avoid extreme values on the scale was not considered to be an important factor. In sum, any artifactual effects on the results due to scale were apparently minor.

<u>Utility functions</u>. The rationale for subjects' responses, as indicated during the post-experimental interviews, was attributed, at least in part, to their concern about the absolute and relative (i.e., with respect to the maximum loan allowable) loan amounts capable of being handled at the branches. Most subjects, for example, felt that loan sizes from \$0 - \$15,000 were sufficiently small for the branches to cope with. Hence, there was a propensity for subjects to adjust their initial decisions upward toward more decentralization. Affecting this factor was the relative loan size. If it was small, then it too motivated an adjustment towards further decentralization. If the initial loan size decision was large relative to the maximum, then the opposite phenomenon occurred. That is, there was a tendency to adjust the initial decision downward toward more centralization ("headquarters must have something to do!"), acting to offset the general tendency toward decentralization based on the absolute loan size per se. This may explain why overestimates for low L^*'s were greater than the underestimates for high L^*'s.

Thus, even though subjects were told to maximize expected profit, they did not appear to act or even attempt to act precisely in this manner, but instead implicitly used some other type of utility function. Suppose subjects employed either a strictly concave (risk averse) or strictly convex (risk seeking) utility function; then (for simplicity, assume the subjects were optimal decision makers) the function in Figure 3 would be below (overcentralized region) or above (over-decentralized region) the 45° line respectively. This can be easily seen by substituting $u(\Delta c)$ for Δc and $u(r)$ for r in equation (3) and choosing a utility scale such that, when the utilities are linear with respect to these attributes, $u(\Delta c) = \Delta c$ and $u(r) = r$. Then, e.g., $u(\Delta c) < \Delta c$ and $u(r) > r$ for the risk averse case and vice versa for the risk seeking case. A risk averse utility function on the attributes Δc, r (and possibly other attributes as well) would thus drive L* down, while a risk seeking utility function would drive L* up.[5] Inasmuch as both overdecentralization and overcentralization occurred, this would then seem to infer that the subject's utility function was doubly inflected (S-shaped); i.e., marginally increasing for small and moderate size loans and marginally decreasing for large loans. This corresponds to the well known Friedman-Savage utility model [1], which appears to provide the underlying rationale for subjects' stated undue willingness to "gamble" on small loans (let the branches handle it; the "risks" are small!), and undue unwillingness (although less so) to "gamble" on large loans. This also corresponds to what one would expect in the real world. On the one hand a manager may be overly reluctant to concern himself with the "trifling, routine" decisions (measured in terms of smallness) and thus may seek every opportunity to reduce this workload to free himself for the "bigger" decisions (while at the same time recognizing the merits of delegating decision making authority to his subordinates). On the other hand he may be quite reticent to let his subordinates make the larger, "more important" decisions (the "risks" are too high) as success now becomes a more important criterion to him. Moreover, peer and subordinate pressure may compel him to act in a way to suggest that he has not overly relieved himself of his decision making responsibilities.

The interpretation of the results is also consistent with the findings of Swalm [7]. In experimentally deriving the utility functions of managers he discovered that the size of the investment involved relative to the manager's customary budget expenditures had a significant effect on the evaluation of proposed investments. Relatively large investments faced harsher scrutiny and were required to possess better prospects than smaller outlays, indicating that size of expenditure played a significant role in determining the fate of the proposal. Swalm also discovered evidence that the managers were cognizant that such an evaluation procedure was contrary to the best interest of shareholders.

The standard deviation and skewness profiles can also be given a utility interpretation. Recall that the standard deviation of the response distributions increased monotonically with increasing loan size. This suggests that individuals' utilities (i.e., portions of their utility functions) were presumably more similar for the small loan sizes, but became increasingly disparate for larger loans (i.e., inter-individual attitudes toward risk diverged as the decision became increasingly important). The positive skewness of the distributions infers that subjects' risk attitudes were more extreme on the risk seeking side of the mean (and median) than on the risk averse side.

A Model of Over-Centralization/Decentralization

A model that predicts the phenomena observed in this study and which is commensurate with a Friedman-Savage utility function resembles a damped sine wave whose functional form is approximated by

$$y_m = x + ae^{-nx}\sin bx$$

where y_m is the mean actual decision, x is the optimal decision, and a, b, and n are general functional parameters (Figure 3). Although this model is rather speculative and certainly not explanatory, if it were shown to be generalizable, it could serve two useful purposes. It could be used descriptively to predict the expected degree of overdecentralization or overcentralization that would eventuate for a given set of conditions (i.e., knowing x, solve for y_m). Or, it could be used prescriptively to determine the optimal decision based on the individual's choice (i.e., knowing y_m, find x).

Implications and Future Research

Subjects used in this study were not high level managers; the task, too, was a simplified abstraction of reality. Therefore one may argue that the results cannot be generalized to actual managerial decision making behavior. However, the subjects were graduate industrial management students, many with considerable business and managerial experience. Moreover, the behaviors observed appeared plausible and, based on conversations with several bank executives, characteristic of what may occur in practice.

Obviously more rigorous and extensive studies need to be performed, both in the laboratory and the field, before any generality is claimed for the results and the model. Some questions which need answering are: (1) How generalizable is the Friedman-Savage utility function as a representation of individual preferences in Reports of Exceptions decisions? (2) How are such decisions affected by adding further task realism such as (a) communication costs, (b) asymmetric error probabilities, (c) permitting a proportion of any defaulted loan to be paid, (d) including the possibility of loss of customers on loans that are delayed as a result of being processed at headquarters, (e) allowing the prior probability of an applicant repaying a loan to be some function of loan size, etc? (3) How is behavior affected by other loan size ranges, (4) role differences (i.e., decisions made or recommended by a branch manager as opposed to the vice president), (5) other decision contexts (e.g., in production, marketing), (6) other ways of conducting the experimental task (e.g., determining Reports of Exception criteria implicitly at the point where each investment decision (e.g., loan application) is made in the hierarchy)?

Especially useful would be to investigate such questions by studying actual decision makers (either past or present decisions) in a real MIS setting.

Appendix. The Model

Let r ≡ profit as a proportion of the loan size

c_h, c_b ≡ scrutiny costs at headquarters and the branches respectively, where $c_b < c_h$.

π ≡ the probability that a loan is good

p_b, p_h ≡ the conditional probability that the branch manager or headquarters respectively refuses a loan when the loan is good (Type I error); it is the same as the conditional probability that the branch manager or headquarters respectively grants a loan when the loan is bad (Type II error); where $p_b > p_h$.

L ≡ the loan size; it is a continous random variable with an unknown probability density function which is positive-valued everywhere.

$f(x)$ ≡ value of probability density function (pdf) of the loan size L at x.

N ≡ expected number of applicants (assumed to be independent of loan size).

The total expected profit (TEP) is then the sum of all the revenues and costs at the branch and headquarters, and is computed as follows:

	At branch	At headquarters
Expected revenue from good loans:	$N\pi(1-p_b)r\int_0^L xf(x)dx$	$N\pi(1-p_h)r\int_L^\infty xf(x)dx$
Expected loss from bad loans:	$N(1-\pi)p_b\int_0^L xf(x)dx$	$N(1-\pi)p_h\int_L^\infty xf(x)dx$
Expected cost of scrutiny:	$Nc_b\int_0^L f(x)dx$	$Nc_h\int_L^\infty f(x)dx$

$$TEP = N\Big\{[\pi(1-p_b)r - (1-\pi)p_b]\int_0^L xf(x)dx + [\pi(1-p_h)r - (1-\pi)p_h]\int_L^\infty xf(x)dx + (c_h-c_b)\int_0^L f(x)dx - c_h\Big\} \qquad (1)$$

(recall: $\int_0^L f(x)dx + \int_L^\infty f(x)dx = 1 \Rightarrow \int_L^\infty f(x)dx = 1 - \int_0^L f(x)dx$

Problem is to maximize TEP, subject to $0 \leq L \leq L_{max}$, if there exists L^* such that

$$\left.\frac{\partial TEP}{\partial L}\right|_{L = L^*} = 0, \qquad \left.\frac{\partial^2 TEP}{\partial L^2}\right|_{L = L^*} < 0. \tag{2}$$

where L_{max} is either the legal loan limit or that established by company policy. Then, since $0 \leq L \leq L_{max}$, optimal $L = \min [\max \{0, L^*\}, L_{max}]$.

Taking the first derivative of (1) with respect to L and satisfying the conditions of (2) yields the following decision rule for L^*

$$L^* = \frac{c_h - c_b}{(p_b - p_h)[1-(1-r)\pi]} = \frac{\Delta c}{\Delta p[1-(1-r)\pi]} \geq 0 \tag{3}$$

Hence optimal $L = \min [\max \{0, L^*\}, L_{max}] = \min [L^*, L_{max}]$ since $L^* \geq 0$, always. If we assume that $L^* \leq L_{max}$, then optimal $L = L^*$. Note that neither the value of the upper loan limit nor the form of the pdf affects (3). The direction in which the optimal value of the critical loan size (L^*) is influenced by Δc, Δp, r, and π can easily be determined by observing (3) directly, or by partially differentiating (3) with respect to each of these variables (i.e., $\frac{\partial L^*}{\partial \Delta c}$, $\frac{\partial L^*}{\partial \Delta p}$, $\frac{\partial L^*}{\partial r}$, and $\frac{\partial L^*}{\partial \pi}$). If the derivative function is > 0 then L^* increases in the variable differentiated by; if < 0, it decreases. Hence, L^* increases in Δc and π, and decreases in Δp and r.

Equation (3) can alternately be derived via a marginal or trade-off analysis. Note that the cost of scrutiny at headquarters is $\$\Delta c$ greater than at a branch. Since $1 - \pi$ customers default, and the Type I and II errors at the branches are Δp greater than at headquarters, a branch will lose, on any given loan,

$$\Delta p[(1 - \pi) L + \pi rL]$$

where $\Delta p(1 - \pi)$ is the joint probability of lending to a bad customer, $\Delta p\pi$ is the joint probability of not lending to a good customer, rL being the profit made on a good loan. Equating the two costs and solving for L yields equation (3). Such an analysis is more nearly like the kind managers would perform. In fact 10% of the subjects did conceptualize the problem and develop the optimal decision rule in this manner.

Extensions

The model for deterimining the optimal loan size in this experiment, although a simplification of reality, could be made more realistic. For instance, actual error probabilities may not be symmetrical, in which case the optimal solution would be

$$L^* = \frac{\Delta c}{\Delta p_B(1-\pi) + \Delta p_G \pi r} \qquad (4)$$

where Δp_B is the probability of a Type I error and Δp_G is the probability of a Type II error. Another variable, the factor rate on defaulted loans (where the proportion of defaulted loans, V, is repaid) could also be included, changing the decision rule to

$$L^* = \frac{\Delta c}{\Delta p_B(1-\pi)(1-V) + \Delta p_G r} \qquad (5)$$

In addition, a loss of customers who have requested a loan above the optimal loan size may result due to the increased time it would take to process the loan application at headquarters rather than at a branch. The model can also incorporate this factor, expanding the decision rule to

$$L^* = \frac{\Delta c + S(r^{\pi}-(1-\pi)(1-V)L^A)p(L > L^*)}{\Delta p_B(1-\pi)(1-V) + \Delta p_G r} \qquad (6)$$

where L^A is the average size of the loan sent to headquarters, $p(L>L^*)$ is the probability that the loan is greater than L^*, and S is the number of people who will go to another bank if the decision is delayed at headquarters. A further complication would be to let $\pi = f(L)$ rather than be a constant (i.e., π is not independent of the loan size but might be, for example, a quadratic function of loan size such that

$$\pi = k(L-L^{o}) + \pi^{o}$$

where k is some constant, L^{o} is the loan size corresponding to a nominal $\pi(=\pi^{o})$. This function could be substituted for π, and the resulting cubic equation solved for L^{*}). The model might further be extended to include multiple criteria.

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Footnotes

1. While a complete sharing of goals and beliefs may seem overly restrictive for most real organizations, it can often provide a reasonable first approximation and can serve as a baseline for studying decision making behavior in real organizations, as well as providing a solid economic basis for MIS thinking [2].

2. The problem is credited to J. Marschak.

3. The mean critical loan sizes for the unlimited group (#5), was significantly greater than those for the comparable limited group (#1) ($F_{1,144} = 4.76$, $p < .03$), however, the medians were not significantly different as verified by the median test. The standard deviation and skewness for like cells were also greater than those of the limited groups, as expected. All these differences were attributed to the several extreme responses exceeding the $15,000 maximum loan limit (for the $540, $2300, $2440, and $12,120 cells there were respectively 0, 3, 2, and 6 responses outside the $15,000 limit in the unlimited group, totalling 11/60 responses).

4. These findings were further supported in subsequent replications and in additional experimentation to obtain more data points at the high relative L* levels.

5. A formal proof of this, using an exponential utility function for money, has been suggested by John Lathrop, University of Michigan, Department of Electrical and Computer Engineering, in personal correspondence with the authors.

Table 1

Actual Versus Optimal Decisions

		Δc_{high}($120)		Δc_{low}($40)	
		r_{high}(.16)	r_{low}(.06)	r_{high}(.16)	r_{low}(.06)
π_{high}(.80)	Δp_{high}(.15)	1,5 $2440[a] $4184[b] $6670 $4000[c] $4000 $3183[d] $7550 .174[e] 1.060	2 $3225 $7446 $9500 $4611 -1.34	3 $815 $3840 $1700 $4239 1.520	4 $1075 $3301 $1965 $3515 1.140
	Δp_{low}(.04)	4 $9160 $9022 $4668 $10279 1.260	1,5 $12120 $10744 $18320 $10135 $12100 $8476 $19294 .213 .970	2 $3055 $6374 $5000 $5336 .773	3 $4040 $7375 $7000 $5152 .218
π_{low}(.60)	Δp_{high}(.15)	3 $1610 $4934 $4500 $3728 .349	4 $1835 $5805 $5084 $5767 .375	1,5 $540 $2353 $1700 $941 $875 $2768 $1854 1.540 1.33	2 $610 $4536 $2660 $4413 1.275
	Δp_{low}(.04)	2 $6060 $8351 $10600 $4670 -1.440	3 $6895 $8928 $8500 $5358 .239	4 $2020 $3797 $2000 $3876 1.390	1,5 $2300 $5067 $7577 $2800 $2300 $4687 $9998 1.450 1.590

Note. - Second set of values along main diagonal are for the group with unlimited loan size. **Groups are indicatedin upper left hand corner. Sample size n for each group are n_1=23, n_2=23, n_3=19, n_4=20, n_5 (unlimited loan size) = 15.**

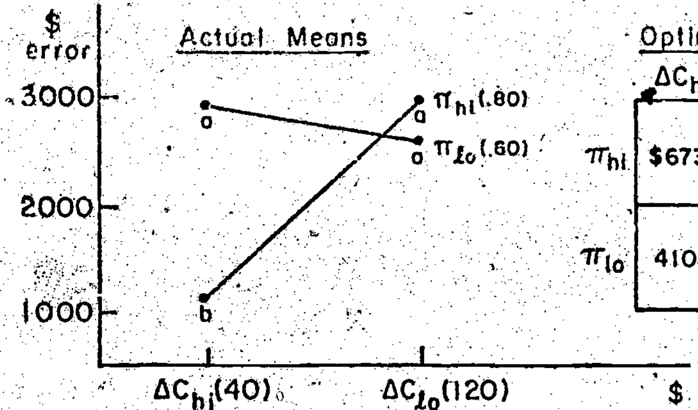
[a] Optimal decisions

[b] Mean of actual decisions

[c] Median of actual decisions

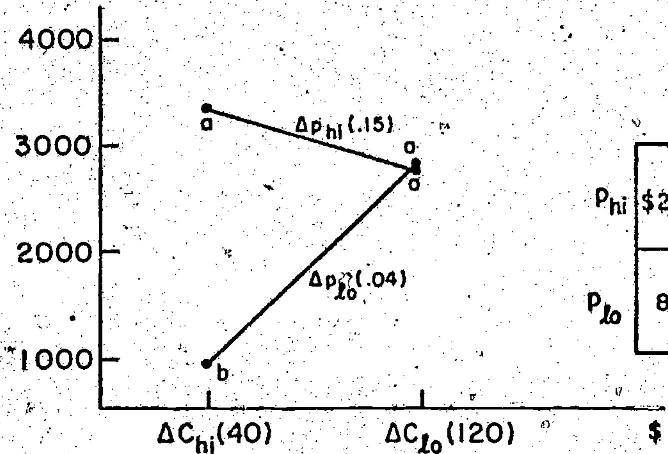
[d] Standard deviation of decision distribution

[e] Skewness of decision distribution

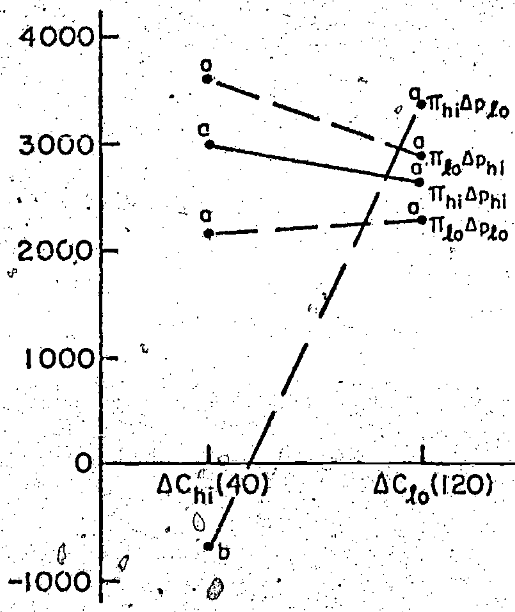


Optimal Means

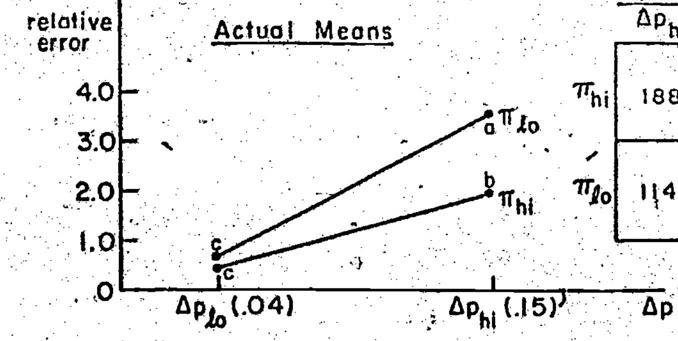
	ΔC_{hi}	ΔC_{lo}
π_{hi}	$6736	2246
π_{lo}	4100	1367



	C_{hi}	C_{lo}
p_{hi}	$2278	760
p_{lo}	8559	2854

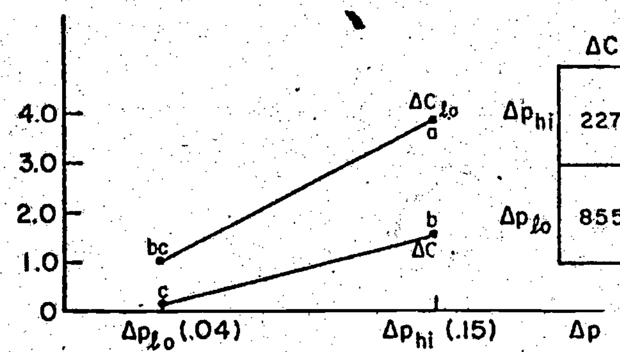


		ΔC_{hi}	ΔC_{lo}
π_{hi}	Δp_{hi}	$ 2833	945
	Δp_{lo}	10640	3548
π_{lo}	Δp_{hi}	1723	575
	Δp_{lo}	6478	2160

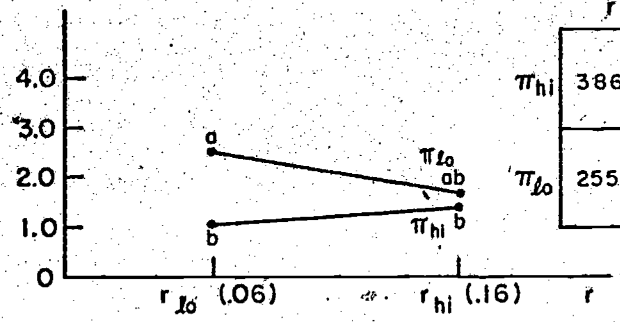


Optimal Means

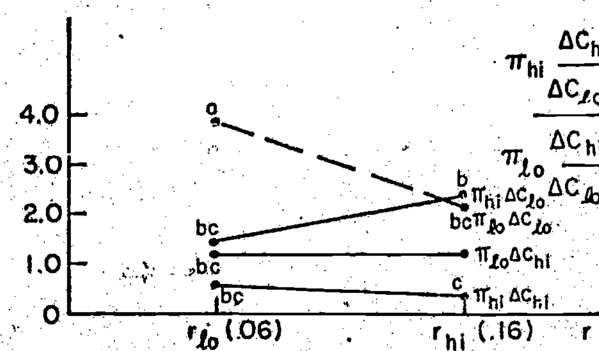
	Δp_{hi}	Δp_{lo}
π_{hi}	1889	7094
π_{lo}	1149	4319



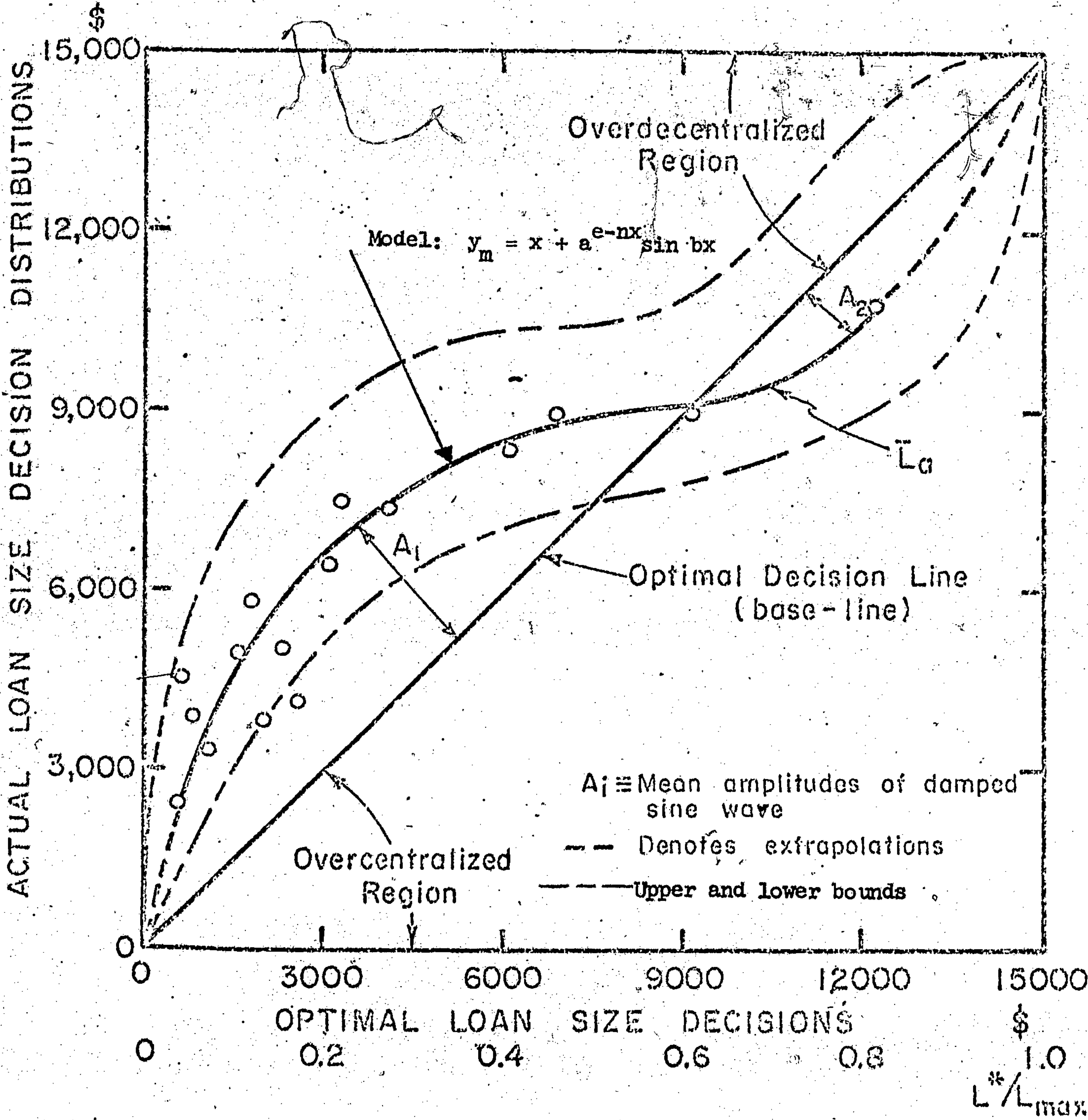
	ΔC_{hi}	ΔC_{lo}
Δp_{hi}	2278	760
Δp_{lo}	8559	2854



	r_{hi}	r_{lo}
π_{hi}	3868	5115
π_{lo}	2558	2910



		r_{hi}	r_{lo}
π_{hi}	ΔC_{hi}	5800	7673
	ΔC_{lo}	1935	2558
π_{lo}	ΔC_{hi}	3835	4365
	ΔC_{lo}	1280	1455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ACTUAL LOAN SIZE DECISION DISTRIBUTIONS
15,000
12,000
9,000
6,000
3,000
0
Overdecentralized Region
Model: $y_m = x + a^{e-nx} \sin bx$
A_2
$\bar{L}_a$
A_1
Optimal Decision Line (base-line)
$A_i \equiv$ Mean amplitudes of damped sine wave
Denotes extrapolations
Upper and lower bounds
Overcentralized Region
0
3000
6000
9000
12000
15000
OPTIMAL LOAN SIZE DECISIONS
$
0
0.2
0.4
0.6
0.8
1.0
L^*/L_{max}

Figure Captions

Fig. 1. Interactions with error as the dependent variable. (Values in the boxes are the mean optimal loan sizes for the specified parameter conditions. Values on the figure having the same letter are not significantly different from each other.).

Fig. 2. Interactions with relative error as the dependent variable. (Values in the boxes are the mean optimal loan sizes for the specified parameter conditions. Values on the figure having the same letter are not significantly different from each other.).

Fig. 3. Actual versus optimal loan size decisions. (Each data point is the mean value of an experimental condition from Table 1 for groups with an upper loan limit (19 to 23 subjects per group). Note the skewness of the response distributions. The extrapolations were determined on the basis that if the problem parameters (π, Δp, Δc, r) were made increasingly extreme driving I^* either toward $0 or $15,000 and beyond (if there were no minimum and maximum loan size limits), eventually all subjects would select the limiting I^* values.).